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ABSTRACT

This study investigated different loci of instructional control and prior background knowledge in terms of two aspects of metacognitive effects (utilization and correctness of metacognitive monitoring) and two aspects of cognitive effects (knowledge acquisition and application). The study also investigated the effectiveness of learner strategies used under learner control. Two parallel versions of computer assisted instruction (CAI) lessons on the computer programming language Logo were developed for the program control and learner control groups. The two versions were the same in the tutorial sessions, but differed in the presentation of the question for self-estimates of understanding and in the choices available in the practice sessions. The subjects were 62 third graders in a suburban elementary school who had no prior experience with Logo, and the study was conducted in the school computer lab over seven weeks. When supportive factors such as provision of clearly labeled options, basic requirements, and presentation of feedback and advice on on-going progress were integrated into the design of a learner control study, this condition seemed to foster students' metacognitive as well as cognitive knowledge and skills in a more effective way than did program control. The overall results of the study indicate that, as an instructional design strategy, learner control can provide learners with opportunities to improve their metacognitive skills and knowledge, while attempting to teach cognitive skills and knowledge of specific subject matter content in a more effective way than can program control. Limitations of the study are noted, and nine tables, copies of the pretest and the interview schedule for metacognitive monitoring, and formulas for the evaluation of the effectiveness of learner strategy are appended. (27 references) (BBM)

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METACOGNITIVE AND COGNITIVE EFFECTS OF DIFFERENT LOCI OF INSTRUCTIONAL CONTROL

With the adoption of microcomputers for education to be used as teaching or learning tools, the design of Computer-Assisted Instructional (CAI) programs has received more emphasis, particularly as such adoption of microcomputers allows for the interaction between learners and instructional materials. One of the issues currently attracting researchers' attention in the area of design of interactive CAI programs is the locus of instructional control: should control of instruction be given to a program (program control) or to a learner (learner control)?

Program control has been the dominant instructional design strategy, utilizing prescribed rules with little or no control given to learners over instructional components. The learner control approach challenges the dominant design strategy by avoiding a rigidly prescribed structure for instruction and emphasizing learners' own decision making in progressing through instruction.

Advocates of the learner control design strategy have discussed its various advantages. Of these possible benefits of learner control in comparison with program control, two were the focus in this study: 1) positive influence on metacognitive and cognitive knowledge and skills, and 2) positive approach to individual differences among learners.

First, one of the most important benefits of learner control is its positive effects on the enhancement of metacognitive and cognitive knowledge and skills through dynamic learning processes. Unlike the program control design strategy, which aims to improve only products of learning, the learner control strategy emphasizes processes as well as products of learning. Under learner control, individual learners are in a position to analyze the nature of a task; to monitor their own understanding of the task; to select activities to be performed; and to decide levels or amounts of instruction needed to extend the present state of knowledge, while continuously monitoring their own cognitive processes and performances. By being aware of control options and deliberately making decisions about the use of the options under learner control, learners can continuously evaluate their progress towards a given objective and attempt to develop effective learning strategies to achieve that objective. As a result, through learner controlled instruction learners may be able to integrate new learning materials more thoroughly within their existing knowledge schema, and enhance their thinking

skills in a more effective way than they may through program controlled instruction.

A second potential advantage of learner control is its positive approach to individual differences among learners. Learner control as an instructional design strategy provides a learner with freedom to follow her/his own interests and needs, and to make decisions about learning rather than being locked into instruction predesigned by an instructor or an instructional designer. In comparison with program controlled instruction, in which a program is predesigned to have control in providing an instructional path best for learners, learner controlled instruction provides more flexible instructional path about which learners can make decisions. Flexibility is the intended outcome of the learner control design strategy. While a dynamic on-going adaptation to an individual learner's varying needs and interests is almost impossible to preplan for program controlled instruction, flexibility provided by learner controlled instruction may make such on-going adaptation possible, and thus interact positively with individual differences.

However, these intuitively appealing theoretical assumptions regarding learner control have received little support from actual research. Although significant efforts have been devoted to research on the locus of instructional control, the results have been diverse, making generalization difficult (Carrier, 1984; Steinberg, 1977). In addition, no previous research on learner control has addressed its metacognitive effects. Therefore, the theoretical assumptions remain as empirical issues requiring research attention.

Purpose

The purpose of the study was to investigate different loci of instructional control and prior background knowledge in terms of two aspects of metacognitive effects (utilization and correctness of metacognitive monitoring) and two of cognitive effects (knowledge acquisition and application). Prior background knowledge refers to the prior knowledge of geometric concepts (distance, direction and pattern) related to the LOGO commands taught in the study.

Three major research goals were established. The first was to investigate the loci of instructional control in terms of the two aspects of metacognitive effects and the two of cognitive effects. In assessing the effects on utilization and correctness of metacognitive monitoring, the Metacomponential Interview developed by Clements and Nastasi (1988) was

adopted, focusing on one of the metacomponents, metacognitive monitoring of solution processes. For the assessment of the effects on knowledge acquisition and application, two versions of computer-delivered tests were developed by the researcher.

The second goal was to extend the investigation in relation to the effectiveness of learner strategies used under learner control. The effectiveness of learner strategies was evaluated on the basis of the following two criteria as recommended by Merrill (1984): accuracy of self-estimates of understanding and appropriateness of control use (Appendix D). To assess the accuracy of self-estimates, at the end of the tutorial session of each lesson students were informed that four practice questions would be presented, and asked to estimate how many of them they could get right. Then, the estimate was compared with the actual number of correct answers in subsequent practice. Concerning the assessment of appropriateness of control use, the frequency of a student's actual uses of control options was recorded by the learner control program, and it was compared with the student's performance in subsequent practice. On the basis of the median of the scores for effectiveness of learner strategy, the total learner control group was partitioned into two subgroups (effective and ineffective learner control subgroups). Comparisons were then made among the program control group and the two learner control subgroups concerning the effects on utilization and correctness of metacognitive monitoring, and on knowledge acquisition and application.

The third goal was to extend the investigation in relation to students' prior background knowledge, as one aspect of individual differences among students. The outcomes of each of the assessments on the two aspects of metacognitive effects and the two of cognitive effects were regressed for each of the loci of instructional control groups on scores of the pretest assessing prior background knowledge. Subsequently, the way in which the outcomes were regressed were compared between the learner control and program control groups.

Research Methods

Learning Materials

LOGO, a computer programming language, was the content area taught. For each of the loci of instructional control groups (program control and learner control groups), two parallel versions of CAI programs were developed and used for the study. The programs were delivered by Apple IIe computers.

Students in both program control and learner control groups were introduced to five basic LOGO commands (i.e., FORWARD, BACK, RIGHT, LEFT and REPEAT) with definitions, rules, examples, and practice. The two versions of the programs were the same in the tutorial session of each lesson, but differed in the presentation of the question for self-estimates of understanding and in the choices available over the use of relevant instructional components in the practice session.

The program for the learner control group consisted of an internally controlled CAI program in which students were free to decide whether and how often they needed to review some instructional components relevant to a practice item with the option of skipping the review. In contrast, the program control group was given an externally controlled CAI program in which all control in the lesson was regulated by the program on the basis of predesigned rules except the instructional pace -- students could advance through instruction when they were ready by pressing the space bar or the return key.

In attempting to find ways to overcome some problems found in other research on the locus of instructional control, the following factors were integrated into the design of instruction and research, as recommended by researchers and theorists. Such integration of supportive factors seemed to be especially important for the learner control group whose time to be devoted to the task was more in their hands than for the program control group. First, in order to motivate students and simulate an actual classroom-like incentive, students were informed that although scores on practice and tests would not impact their class grades, their teachers would look at their scores (Tennyson, 1980; Tennyson and Buttrey, 1980). Second, students were required to solve a certain number of practice items to assure that they did not bypass important instructional components (Kinzie, 1988; Steinberg, 1977; Waldrop, 1984). Third, prior to the instruction, there was a pretraining period to help students become familiar with computers and the novel learning system, perform conscious cognitive information processing, and understand the objectives, procedures and values involved in building their own learning strategies (Gay, 1986; Hannafin, 1984; Kinzie, 1988; Merrill, 1984; Schmitt and Newby, 1986; Steinberg, 1977).

In addition, the following two factors were integrated into the design of learner controlled instruction as recommended by other researchers and theorists. Control options were clearly labeled and

presented in a menu format for easy use of the options (Reigeluth and Stein, 1983). Students were asked to estimate how many of the subsequent practice questions they would get right so that they could be specifically guided to evaluate their own understanding of the given learning material (Garhart and Hannafin, 1986; Merrill, 1984). Also, immediate feedback, continuous advice on students' on-going progress and summaries of their uses of control options were presented in order to help students make informed decisions about their own learning (Hannafin, 1984; Kinzie, 1988; Lepper and Malone, 1987; Markman, 1977; Merrill, 1984; Tennyson, 1980; Tennyson and Buttrey, 1980; Waldrop, 1984).

Subjects

The subjects of the study were 62 third graders enrolled in a suburban elementary school in Wisconsin during the spring of 1990. None of the students participating in the study had prior experience with LOGO.

Procedures

The study was conducted in the school microcomputer lab over seven weeks. When students arrived at the lab, they were seated in front of the computers that showed their names on the screen and contained the instructional program versions assigned to them. Students worked with computers individually. Each participating student took lessons and assessments through eight sessions, and had an interview.

In the first session, a pretest was administered to assess students' prior background knowledge (Appendix B). Then, before instruction began, on the basis of the pretest scores students were randomly assigned to either the learner control or the program control group. To keep the levels of students' prior background knowledge as equal as possible, a Yoked Randomized Assignment method (Cohen, 1969) was utilized. As the result, 31 students were assigned to each locus of instructional control group.

The next five sessions were used for lessons on LOGO commands. Before the first lesson began, a short introductory training period was given to students to help them become familiar with computers and instructional programs and understand the objectives, procedures and values related to the use of the programs. In the sessions for lessons, students who finished a lesson earlier than the others were asked to remain in the lab and spend the rest of the session with a paper and pencil maze task in order to encourage students to devote adequate efforts to their given computer tasks.

Upon the completion of all the lessons, the seventh and eighth sessions were used for posttests on knowledge acquisition and application. For the assessment of knowledge acquisition, a 20-item posttest was administered to students. In the test, items similar to the practice ones embedded in lessons were presented to evaluate students' abilities to recall the LOGO commands taught throughout the study. The number of test items on each LOGO command was equally balanced across all the commands taught. For the assessment of knowledge application, given the length of each side of a square on the screen, students were asked to draw a square by entering commands for turtle moves and turns. Both tests were delivered by computers.

The interview on metacognitive monitoring was conducted with individual students after all the lessons were over. Four questions were asked, with five prompts for each question (Appendix C). The entire interview process was recorded on audio tape for later analysis and testing of inter-coder agreement on scoring. When the inter-coder agreement was tested, the Cronbach's α reliability values were .8700 for the utilization of metacognitive monitoring, and .9864 for the correctness of metacognitive monitoring.

Hypotheses

The following hypotheses were examined in relation to the three respective research goals. For the first and third goals, the hypotheses were made for confirmatory purposes. In contrast, for the second goal, the hypothesis was made for an exploratory purpose.

1) There will be differences in means between the program control group and the learner control group, in favor of the latter group, in the assessments of two aspects of metacognitive effects (utilization and correctness of metacognitive monitoring) and two of cognitive effects (knowledge acquisition and application).

2) There will be differences in means among the program control group and the two learner control subgroups partitioned according to the effectiveness of learner strategy, in the assessments of utilization and correctness of metacognitive monitoring and knowledge acquisition and application.

3) There will be differences between the program control group and the learner control group in the ways in which the outcomes of each assessment are regressed on the scores of a test assessing prior background knowledge; the slopes of the regressed outcomes of each assessment will be steeper for the program control group than for the learner control group.

Data Analyses and Results

Data analyses and their results are discussed below, in response to the hypotheses made for each of the three research goals.

Investigation of Metacognitive and Cognitive Effects of the Loci of Instructional Control

In serving the first goal of the study, the program control group was compared with the learner control group in the assessments of the two aspects of metacognitive effects and the two of cognitive effects.

A one-tailed t test was employed in comparing mean scores of the two groups in those assessments (Tables 1 and 2). Significant differences between the two groups were found in favor of the learner control group in all the assessments. Thus, the results of the t test supported the first research hypothesis.

Insert Table 1 and Table 2 about here

Extended Investigation in Relation to Effectiveness of Learner Strategy

For the second goal of the study, the investigation of the loci of instructional control was extended in relation to the effectiveness of learner strategy used under learner control. A descriptive data analysis was conducted on the accuracy of self-estimates of understanding, appropriateness of control use and effectiveness of learner strategy (Tables 3, 4 and 5). The analysis showed similar distributions for accuracy, appropriateness and effectiveness across possible ranges of scores.

Insert Table 3, Table 4 and Table 5 about here

To permit a further investigation of the metacognitive and cognitive effects of the two loci of instructional control, the learner control group was partitioned into two subgroups (effective and ineffective learner control subgroups) according to the effectiveness of learner strategy. Then a one-way analysis of variance (ANOVA) was conducted to compare mean scores of the two learner control subgroups and the program control group in the assessments of the two aspects of metacognitive effects and the two of cognitive effects (Tables 6 and 7). As hypothesized, concerning the metacognitive effects, significant differences were found among the three groups in the assessments of both aspects: utilization and correctness of metacognitive monitoring. However, concerning the cognitive effects, a significant difference was found in the assessment of one aspect,

knowledge acquisition. In the assessment of knowledge application, although a statistically significant difference was not found, the learner control subgroups, especially the effective learner control subgroup, demonstrated better performance than the program control group.

Insert Table 6 and Table 7 about here

In addition to the ANOVA, to determine where significant differences were, Fisher's least significant difference test was employed for multiple pairwise comparisons among the three groups at the familywise $\alpha=.05$ level (Table 8). The comparisons were made with the mean scores of each of the assessments for the three dependent variables for which significant differences were found from the ANOVA: utilization of metacognitive monitoring, correctness of metacognitive monitoring, and knowledge acquisition. The comparisons between the effective learner control subgroup and the program control group revealed that the former group demonstrated significantly better performance than the latter group in the assessments of all of the three dependent variables. Between the ineffective learner control subgroup and the program control group, significant differences were found in favor of the former group only in the assessments of the two variables measuring metacognitive effects, namely, utilization of metacognitive monitoring and correctness of metacognitive monitoring. Furthermore, between the two learner control subgroups, no significant difference was found in any assessment.

Insert Table 8 about here

Extended Investigation in Relation to Students' Prior Background Knowledge

In serving the third goal of the study, the investigation of the metacognitive and cognitive effects of the loci of instructional control was extended in relation to learners' prior background knowledge.

A regression analysis was used to test the relative contribution of students' prior background knowledge to each of the assessments of the two aspects of metacognitive and the two of cognitive effects. For each locus of instructional control group, the outcome of each of the assessments was regressed on the scores of a pretest assessing prior background knowledge (Table 9).

Insert Table 9 about here

Then, to test whether the regression lines of the two loci of instructional control groups were parallel for each assessment, equality of the regression slopes for the two groups was tested according to standardized procedures (Finn, 1974, 376-378; Rao, 1973, 281-284). The regression slopes turned out to be steeper for the program control group than for the learner control group for each of the assessments. However, the results of the test indicated that the slopes of the regression lines on each assessment were statistically the same for the learner control and the program control groups: $F(1,58) = 0.0658$, n.s. for utilization of metacognitive monitoring; $F(1,58) = 1.4702$, n.s. for correctness of metacognitive monitoring; $F(1,58) = 0.4181$, n.s. for knowledge acquisition; and $F(1,58) = 1.4083$, n.s. for knowledge application. Thus, the third research hypothesis formulated in this study was not supported by these results.

Discussion

In attempting to find ways to overcome problems that students, especially those with relatively low levels of prior background knowledge, may have under learner control, supportive factors such as provision of clearly labeled options, basic requirements, and presentation of feedback and advice on on-going progress were integrated into the design of instruction. When these supportive design elements were integrated into the design of a learner control study, learner control seemed to foster students' metacognitive as well as cognitive knowledge and skills in a more effective way than did program control. The overall performance of the students under learner control was significantly better than that under program control in the assessments of two aspects of metacognitive effects (utilization and correctness of metacognitive monitoring) and two of cognitive effects (knowledge acquisition and application).

In fact, under learner control, learners become responsible for their own learning, practice conscious reflection on their cognitive abilities, task demands and learning strategies, and learn how to manage their own thinking processes and learning activities. Thus, in those processes, a learner can be led to enhance her/his metacognitive monitoring skills to perform and behave strategically. At the same time, in such learning processes more cognitive burden is given to a learner and thus s/he can improve her/his ability to acquire knowledge more thoroughly and to apply the acquired knowledge to other tasks.

It has been stressed that in addition to the concern with teaching content-specific skills and

knowledge, educators need to pay attention to teaching of content-general skills and knowledge requiring high level thinking (Bonner, 1988; Chipman and Segal, 1985; Gagne and Glaser, 1987; Perkins and Salomon, 1989; Schmitt and Newby, 1986). Metacognitive skills and knowledge are one area that needs such attention. On this point, metacognitive skills and knowledge do not automatically improve as age increases, so an attempt must be made to provide learners with opportunities to learn and practice such skills and knowledge (Brown, 1980; Markman, 1977; Schmitt and Newby, 1986). The present study shows the potential of learner control as an instructional design strategy that may provide learners with opportunities to improve metacognitive skills and knowledge, while attempting to teach skills and knowledge of specific subject matter content.

However, the pairwise comparisons between each of the learner control subgroups and the program control group indicate the crucial need for accurate self-estimates of understanding and appropriate uses of control options to achieve the full potential of learner control in enhancing both metacognitive and cognitive skills and knowledge. In spite of the integration of the supportive factors into the design of instruction, there was still a wide range in the distribution of data on accuracy of self-estimates of understanding, appropriateness of control use and effectiveness of learner strategy.

Furthermore, concerning students' prior background knowledge, a post hoc analysis of data indicated that under learner control, students who exhibited relatively high levels of prior background knowledge were significantly more capable of making accurate self-estimates of understanding and appropriate uses of control options, and thus of utilizing effective learner strategies, than were those with low levels of prior background knowledge: $F(1,29)=4.219$, $p<.05$ for accuracy of self-estimates of understanding; $F(1,29)=24.543$, $p<.001$ for appropriateness of control use; and $F(1,29)=15.400$, $p<.001$ for effectiveness of learner strategy. Students with low levels of prior background knowledge tended to estimate their own understanding inaccurately and to use the control options too infrequently.

These findings on individual differences in prior background knowledge indicate that students' prior knowledge of concepts relevant to those being taught is important in helping them to understand the underlying structure of a given instruction, to develop effective learning strategies, and thus to enhance metacognitive and cognitive knowledge and skills. As Snow (1980) contended, learner controlled instruction may not

overcome the fact that "individual characteristics not under control of the individual will determine to a significant extent what and how much that individual will learn in a given instructional setting" (p.1).

Overall, students in the learner control group demonstrated significantly better performance than those in the program control group in the assessments of metacognitive and cognitive effects, regardless of their individual differences in prior background knowledge. This finding contradicts those of some previous research on learner control (Goetzfried and Hannafin, 1985; Hannafin, 1984; Kinzie, 1988; Krendle and Liberman, 1988; Steinberg, 1977), which supported the Achievement-Treatment Interaction theory (Tobias, 1976); for students with a low level of prior knowledge, learner control is less effective than program control, and for those with a high level of prior knowledge, learner control is more effective than (or comparable to) program control. However, although it was theoretically assumed that learner control as an instructional design strategy would serve identified individual differences among learners better than would program control in accomplishing the goal of instruction, the inequity among learners resulting from individual differences was preserved by learner control in the same way as by program control.

The magnitude of individual differences typically confronting instructional designers and the evidence of the relationship between such differences and achievement explain why only a few students in most classrooms fall into the category of "success". The majority of students need some type of support, and thus a variety of supporting strategies must be investigated and integrated into the design of instruction. This applies to the design of learner controlled instruction as well. Further investigation is needed of supportive factors that can take over some of the burdens that learners may have and that may interact with a variety of characteristics of individual differences.

The overall results of this study indicate that as an instructional design strategy, learner control can provide learners with opportunities to improve metacognitive skills and knowledge, while attempting to teach cognitive skills and knowledge of specific subject matter content in a more effective way than can program control. These results were apparent across learners' prior background knowledge of relevant subject matter. However, it must be recognized that this study was conducted in introductory instruction, with a relatively limited application of control options, for a short time period. Considering the

potentially rich learning environment that learner control can create, further research efforts should be devoted to the development of instructional models of learner control from which all learners can benefit in enhancing both metacognitive and cognitive skills and knowledge.

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APPENDIX A
Tables

Table 1

Means and Standard Deviations of Dependent Variables

Variable	Maximum Score	L		P		ALL	
		Mean	SD	Mean	SD	Mean	SD
utilization of monitoring	24	14.65	3.30	11.42	3.30	13.03	3.66
correctness of monitoring	24	12.77	2.54	9.39	4.15	11.08	3.81
knowledge acquisition	40	25.65	6.70	22.06	8.17	23.85	7.63
knowledge application	70	54.97	14.70	45.65	19.78	50.31	17.91

Note. L = learner control group
P = program control group

Table 2

Results of t Test on Dependent Variables between the
Learner Control and Program Control Groups

Variable	D.F.	t	
		Value	One-tail Prob.
utilization of monitoring	60	3.84	.000***
correctness of monitoring	60	3.88	.000***
knowledge acquisition	60	1.89	.032*
knowledge application	60	2.11	.020*

*.01 < p < .05. ***p <= .001.

Table 3

Descriptive Data on Accuracy of Self-estimates of Understanding

mean	median	SD
2.503	2.400	.563

Histogram Frequency

Count	Midpoint	
0	1.00	
1	1.20	*****
0	1.40	
1	1.60	*****
2	1.80	*****
3	2.00	*****
1	2.20	*****
10	2.40	*****
3	2.60	*****
4	2.80	*****
2	3.00	*****
1	3.20	*****
1	3.40	*****
1	3.60	*****
1	3.80	*****
0	4.00	

I.....+.....I.....+.....I.....+.....I.....+.....I.....+.....I

0 2 4 6 8 10

Table 4

Descriptive Data on Appropriateness of Control Use

mean	median	SD
2.348	2.400	.611

Histogram Frequency

Count	Midpoint	
2	1.00	*****
0	1.20	
1	1.40	*****
2	1.60	*****
0	1.80	
4	2.00	*****
4	2.20	*****
7	2.40	*****
3	2.60	*****
1	2.80	*****
3	3.00	*****
3	3.20	*****
1	3.40	*****
0	3.60	
0	3.80	
0	4.00	

I.....+.....I.....+.....I.....+.....I.....+.....I.....+.....I

0 2 4 6 8 10

Table 5

Descriptive Data on Effectiveness of Learner Strategy

<u>mean</u>	<u>median</u>	<u>SD</u>
2.426	2.400	.522

Histogram Frequency

<u>Count</u>	<u>Midpoint</u>	
0	1.00	
1	1.10	*****
0	1.20	
0	1.30	
0	1.40	
1	1.50	*****
0	1.60	
1	1.70	*****
0	1.80	
1	1.90	*****
1	2.00	*****
3	2.10	*****
3	2.20	*****
1	2.30	*****
5	2.40	*****
2	2.50	*****
3	2.60	*****
4	2.70	*****
1	2.80	*****
0	2.90	
0	3.00	
0	3.10	
2	3.20	*****
0	3.30	
1	3.40	*****
0	3.50	
1	3.60	*****
0	3.70	
0	3.80	
0	3.90	
0	4.00	

1.....1.....1.....1.....1.....1.....1.....1.....1.....1
0 1 2 3 4 5

Table 6

Means and Standard Deviations of Dependent Variables

Variable	Maximum Score	E-L		IE-L		P	
		Mean	SD	Mean	SD	Mean	SD
utilization of monitoring	24	14.94	3.80	14.33	2.77	11.42	3.30
correctness of monitoring	24	13.25	2.65	12.27	2.40	9.39	4.15
knowledge acquisition	40	27.75	6.26	23.40	6.61	22.06	8.17
knowledge application	70	58.44	9.78	51.27	18.22	45.65	19.78

Note. E-L = effective learner control subgroup
 IE-L = ineffective learner control subgroup
 P = program control group

Table 7

Results of ANOVA on Dependent Variables among the Two
Learner Control Subgroups and the Program Control Group

variable	source of variation	D.F.	mean square	F Ratio	F Prob.
utilization of monitoring	between group	2	82.058	7.428	.001***
	within group	59	11.048		
correctness of monitoring	between group	2	92.654	7.795	.001***
	within group	59	11.886		
knowledge acquisition	between group	2	172.611	3.180	.049*
	within group	59	54.279		
knowledge application	between group	2	872.605	2.889	.064
	within group	59	302.033		

*.01 < p < .05. ***p <=.001.

Table 8

Results of Fisher's Least Significant Difference Test

utilization of metacognitive monitoring

	G1	G2	G3
G1			
G2			
G3	*	*	

correctness of metacognitive monitoring

	G1	G2	G3
G1			
G2			
G3	*	*	

knowledge acquisition

	G1	G2	G3
G1			
G2			
G3	*		

Note. G1 = effective learner control subgroup
 G2 = ineffective learner control subgroup
 G3 = program control group

Table 9

Results of Regression of Dependent Variables on Pretest Scores

group	r ²	b	statistical value
utilization of metacognitive monitoring			
learner control	.0002	.020	F(1,29) = .005
program control	.0086	.116	F(1,29) = .252
correctness of metacognitive monitoring			
learner control	.0217	.176	F(1,29) = .642
program control	.1540	.615	F(1,29) = 5.281*
knowledge acquisition			
learner control	.1457	1.205	F(1,29) = 4.946*
program control	.2954	1.679	F(1,29) = 12.158**
knowledge application			
learner control	.0218	1.022	F(1,29) = .645
program control	.1823	3.192	F(1,29) = 6.464*

*.01 < p < .05. **.001 < p < .01.

APPENDIX B

Pretest

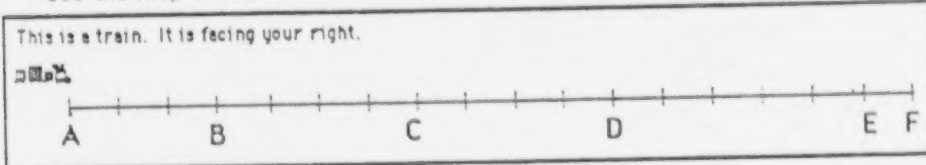
Your name: _____

- 1] This railroad has been marked in units called blocks.
Each block is  long.



A train runs on this railroad.

Use the map of the railroad to help answer the questions below.



- ONE: If the train started at the station B and went to the station E,
how many blocks did it move?

Answer: _____ blocks

- TWO: The train started at the station C and moved forward 4 blocks.
Where did it stop?

Answer: at the _____ station

- THREE: The train moved backward 5 blocks.
If it ended at the D station, where did it start?

Answer: at the _____ station

- FOUR: The train started at the station F.
When it left there, it moved backward 5 blocks.
How much farther did it have to go to get to the station C?

Answer: _____ blocks farther

- FIVE: The train moved forward 4 blocks and then backward 11 blocks.
If it ended at the A station, where did it start?

Answer: at the _____ station

2] Find the pattern and
select the shape that comes next.

ONE:



A



B



C

Answer: _____

TWO:



A



B



C

Answer: _____

THREE:



A



B



C



D

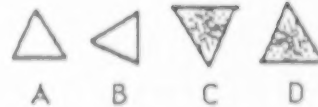
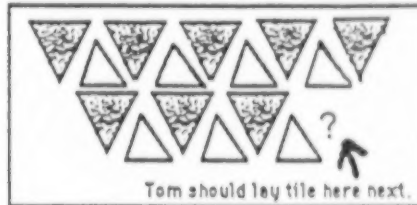
Answer: _____

3] Tom is helping his father lay tile in their kitchen.

Which tile, without turning, should Tom use next?

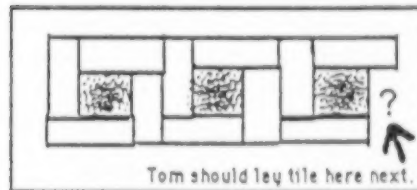
Select the answer among the given choices.

ONE:



Answer: _____

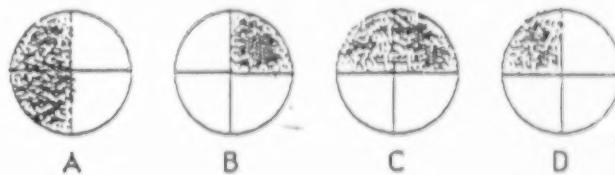
TWO:



Answer: _____

4] If you turn this figure a half turn to the right, what will the figure look like after the turn?

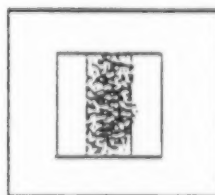
Select the answer among the given choices.



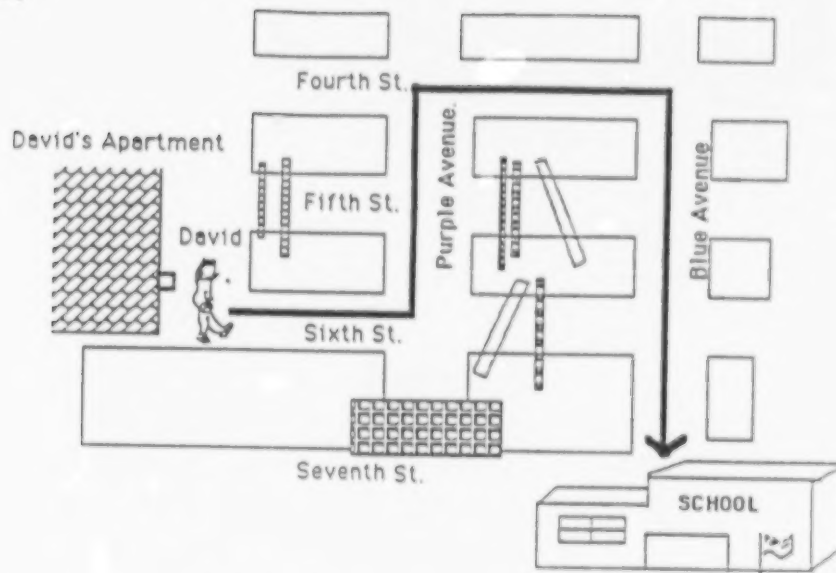
Answer: _____

5] If you turn this figure a quarter turn to the left, what will the figure look like after the turn?

Select the answer among the given choices.



Answer: _____



Suppose you have to call David to give him directions to get from his apartment house to school.

You have the map, but David doesn't.

As you can see on the map, some roads are closed, so David should follow the path marked on the map.

Answer: Walk along Sixth Street until you come to Purple Avenue, and then turn to the ~~LEFT~~ RIGHT. (Circle one.)

Walk along Purple Avenue until you come to Fourth Street, and then turn to the LEFT ~~RIGHT~~. (Circle one.)

Walk along Fourth Street until you get to Blue Avenue, and then turn to the LEFT ~~RIGHT~~. (Circle one.)

Walk along Blue Avenue until you come to the school.

APPENDIX C
Interview on Metacognitive Monitoring

Question #1

Every classroom in Mary's school will have 2 girls for every boy. Mary found out that there will be 8 girls in her class, so she figured there would be 16 boys. Her sister's class will have 10 girls. How many boys do you think will be in her sister's class?

Prompts:

1. Do you have to watch out for mistakes when you do this problem?
2. Is there something in the problem that could trick you if you were not careful?
3. Is Mary right when she figures that there will be 16 boys in her class?
4. Will a classroom with 2 girls for every boy have 2 times as many boys? Is that a mistake? Or half as many boys?
5. Be careful not to make a mistake. If there were 2 girls, and there are 2 girls for every boy, then there would be 1 boy. Half as many boys. If there were 4 girls, then there would be 2 boys. Half as many boys. (Continue if child does not understand until the 8/4 problem of Mary's is solved.)

Question #2

A railroad company discovered that when trains get into an accident, the people in the last car are hurt the most. The last car is the most dangerous. So Sue told them to take off the last car. They did. The train was in an accident. What do you think happened to the people?

Prompts:

1. Do you have to watch out for mistakes when you do this problem?
2. Is there something in the problem that could trick you if you were not careful?
3. Is Sue right when she figures that, if you take off the last car, less people will get hurt?
4. What will happen when you take off the last car? Was there a mistake? Is any car the most dangerous then?
5. Don't make a mistake. If you take off the last car, what would be at the end of the train? Is that car now the last car? Would that car be the most dangerous?

Question #3

When Albert was 6 years old, his sister was 3 times as old as he. Now he is 10 years old and he figures that his sister is 30 years old. How old do you think his sister will be when Albert is 12 years old?

Prompts:

1. Do you have to watch out for mistakes when you do this problem?
2. Is there something in the problem that could trick you if you were not careful?
3. Is Albert right when he figures that when he is 10 years old his sister is 30 years old?
4. Will his sister always be 3 times as old as Albert? Is that a mistake? Should you multiply or add years?
5. Don't make a mistake. When Albert was 6, his sister was 18. 12 years older. What would his sister be 1 year later, when Albert was 7? (19) 12 years older. One year later? (Continue if child does not understand, until solve 10/22 problem of Albert's.)

Question #4

At our school the track is in a circle with six flags spaced equally around it. Yesterday, Frank started at the first flag and raced around the circle. He took 2 minutes to get to the third flag. He thought it would take him 2 more minutes to get to the sixth flag if he kept on at the same rate. How long did it take him to get all of the way around the track?

prompts:

1. Do you have to watch out for mistakes when you do this problem?
2. Is there something in the problem that could trick you if you were not careful?
3. Is Frank right when he figures that it would take him 2 more minutes to get to the sixth flag?
4. Is it the same distance from the first to the third as from the third to the sixth flag? Is that a mistake? Where does he start? How many flags is it to the third flag starting at the first flag?
5. Don't make a mistake. Pretend Frank starts at the first flag, then goes to the second, then the third flag. That takes him 2 minutes. How long will it take him to get to the fourth, then the fifth flag? (The sixth?)

APPENDIX D
Evaluation of Effectiveness of Learner Strategy

Accuracy of Self-Estimates of Understanding

If SELF-EST = 1 & SCORE = 0, 5 or 10, then ACCURACY = 4.
 If SELF-EST = 1 & SCORE = 15 or 20, then ACCURACY = 3.
 If SELF-EST = 1 & SCORE = 25 or 30, then ACCURACY = 2.
 If SELF-EST = 1 & SCORE = 35 or 40, then ACCURACY = 1.

If SELF-EST = 2 & SCORE = 0, 5 or 10, then ACCURACY = 3.
 If SELF-EST = 2 & SCORE = 15 or 20, then ACCURACY = 4.
 If SELF-EST = 2 & SCORE = 25 or 30, then ACCURACY = 2.
 If SELF-EST = 2 & SCORE = 35 or 40, then ACCURACY = 1.

If SELF-EST = 3 & SCORE = 0, 5 or 10, then ACCURACY = 1.
 If SELF-EST = 3 & SCORE = 15 or 20, then ACCURACY = 2.
 If SELF-EST = 3 & SCORE = 25 or 30, then ACCURACY = 4.
 If SELF-EST = 3 & SCORE = 35 or 40, then ACCURACY = 3.

If SELF-EST = 4 & SCORE = 0, 5 or 10, then ACCURACY = 1.
 If SELF-EST = 4 & SCORE = 15 or 20, then ACCURACY = 2.
 If SELF-EST = 4 & SCORE = 25 or 30, then ACCURACY = 3.
 If SELF-EST = 4 & SCORE = 35 or 40, then ACCURACY = 4.

Note. SELF-EST = self-estimates of understanding
 SCORE = score in a practice session in a lesson
 ACCURACY = accuracy of self-estimates of understanding

Appropriateness of the Use of Control Options

If NOWRONG - NOREVIEW $\leq$ 0, then APPROPRIATENESS = 4.
 If NOWRONG - NOREVIEW = 1 or 2, then APPROPRIATENESS = 3.
 If NOWRONG - NOREVIEW = 3 or 4, then APPROPRIATENESS = 2.
 If NOWRONG - NOREVIEW = 5 or 6, then APPROPRIATENESS = 1.
 If NOWRONG - NOREVIEW = 7 or 8, then APPROPRIATENESS = 0.

Note. NOWRONG = the number of wrong answers in a practice session in a lesson ($\text{NOWRONG} = 8 - \text{SCORE}/5$)
 NOREVIEW = the number of review options used
 APPROPRIATENESS = appropriateness of the use of control options

Effectiveness of Learner Strategy

$\text{EFFECTIVENESS} = (\text{ACCURACY} + \text{APPROPRIATENESS}) / 2$

Note. EFFECTIVENESS = effectiveness of learner strategy
 ACCURACY = accuracy of self-estimates of understanding
 APPROPRIATENESS = appropriateness of the use of control options